In order to provide comparative data using a different test method, one set of tests was performed with the interfering source fixed at channel 29 and the TV receiver tuned to various channels from 14 to 37.

Filtering of Undesired Signals

DTV interference rejection testing requires extremely high suppression of out-of-band emissions from the undesired signal that might otherwise spill into the desired channel. Available signal generators do not provide sufficient suppression

The conventional approach to dealing with this issue is to place a bandpass filter around the *undesired* signal. In that approach the undesired signal **is** typically placed on a fixed channel *so* that a fixed filter can be used. The desired signal and the TV tuner are then switched to various channels to achieve the channel-spacings to be tested.

For this report a different approach was taken to the problem. The desired channel was fixed and the undesired channel was varied. **A** fixed band-reject filter was used to suppress the out-of-band emissions of the undesired signal that fell *within the desired channel.* The details of the technique are provided in Chapter **4.** Tests using the conventional approach are reported in Chapter 14 for comparison.

Operation and Connection of Samples

For receivers having multiple antenna inputs that could handle ATSC signals, only the input labeled "antenna A" or "antenna 1" was tested. For receivers having a radio frequency (W)output associated with the selected antenna input, the output was externally terminated in 75 ohms.

Only one TV was turned on during any given test in order to avoid possible interference from emissions of other TV receivers.

Identifying Interference Rejection Thresholds

In determining interference thresholds, we are interested in picture degradation that is visible to the TV viewer. With digital television, some data transmission errors are fully corrected by error correction algorithms — resulting in no errors in the video transport stream data. Other transmission errors that cannot be corrected may, in some cases, be effectively masked by error concealment techniques used in the receiver's video processor. We are only interested in picture errors that will be perceived by the viewer. The subjectivity of visual error detection could be eliminated through relationships that have been established between visible TOV and bit-error-rate (BER); however, such techniques cannot be applied in testing of consumer DTV receivers that do not provide access to bit streams; consequently, thresholds for this report were determined by visual observation of DTV pictures.

In all interference rejection tests, the level of the desired signal D was adjusted as closely as possible to the intended value by using a step attenuator operating in 0.1-dB steps. The level of the undesired (interfering) signal was then adjusted upward until picture errors were easily observed within a few seconds. That level was then backed off and readjusted in 0.1-dB steps to determine the minimum undesired signal level at which one or more visible picture errors occurred in two consecutive 30-second intervals. The power level of the undesired signal was then measured and this level was identified as the undesired power level U at TOV—except in rare cases as described below.

The thresholds exhibited a strong "cliff effect". In most cases, the increasing interference level about 1 dB above the TOV level identified by the method above caused complete loss of picture. In some cases, picture **loss** did not occur until the undesired signal level rose as much as much as 3 dB and in one case. **5** dB. In a few cases, picture loss occurred concurrently with the appearance of errors or with only an additional 0.1 dB increase in interference — an extremely abrupt cliff!

When the picture was lost due to high interference levels, it was recovered in most cases by reducing the undesired signal level back to the TOV level that was identified by the procedure described above, though in some cases that recovery took 20-seconds or more. In a few cases, it was observed that--.-after loss of picture due to either high interference levels or a channel change — the TV was unable to re-establish a picture without reducing the undesired signal level a few tenths of a dB below the apparent TOV point. In such cases, the threshold was rerecorded as one 0.1-dB step above the level necessary to permit picture recovery. (*i.e.*, inability to recover the picture was treated as an error.)

DIU ratios were computed based on the actual measured value of the desired signal D rather than on the intended setting of D (though the difference was generally less than 0.05 dB).

Signal Power Measurements

All measurements of desired and undesired power levels were made by means of the band power integration function of a spectrum analyzer that was set to perform an RMS average of spectrum traces. The number of points in the spectrum sweep was set *so* that bin spacing matched the 30 kHz resolution bandwidth used for the measurements. The spectrum analyzer's internal preamp was used to ensure a sufficiently low instrumentation noise level (approximately -9X dBm in 6-MHz bandwidth **+** analyzer attenuation). The analyzer was used in the automatic attenuation mode with the reference level set to the lowest multiple of **5** dBm that was at least 1 dB above the total signal power. In cases where power levels below -70 dB were to be measured, the analyzer attenuation was manually set to 0 dB. For measurements below -78 dBm (measurements of desired signal level at or near the receiver threshold), analyzer noise was measured separately and subtracted — in linear power units — from the measured values.

PRESENTATION OF RESULTS

Interference *rejection performance* measurements on TV receivers are typically presented in terms of the ratio of desired to undesired signal powers (D/U) at TOV. *Protection* **criteria** designed to prevent interference are sometimes specified in terms of DIU ratios and at other times specified as absolute signal levels (*e.g.*, of transmit power or field strength) permitted in a band.

DIU rejection ratios would provide a particularly useful characterization of interference rejection performance of a receiver if those rejection ratios remained constant as signal levels were varied. Unfortunately, we found this not to be the case for DTV receivers. Interference at many channel offsets is driven by nonlinear mechanisms that cause DIU to increase with increasing signal levels; such variability **is** particularly common at low desired signal levels where a TV is most susceptible to interference.' Even for linear interference mechanisms, D/U increases **as** the desired signal level approaches D_{MIN} for a receiver.

Since DIU rejection ratios of DTV receivers are not constant, interference assessment requires knowledge of the **absolute levels** of desired and undesired signals at the input to the receiver rather than just a knowledge of the *ratio* of the signal powers. But, the absolute signal levels at the input to a DTV receiver can vary widely depending on the gain, height, or indoor-versus-outdoor placement of the antenna to which it is attached. Table 2-4 shows UHF reception examples for three different antenna systems:
- An outdoor antenna system with a mast-mounted preamp sufficient to overcome downlead **loss:**
- An outdoor antenna system according to OET-69 planning factors;
- A low-gain, indoor antenna.

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* We show later in this report that **a** tuner's automatic gain control (**AGC**) can "stabilize" the effects of nonlinear interference mechanisms resulting in a more constant value of D/U at higher signal levels.

The table shows that the signal level at the TV's RF input can easily vary over a 26-dB range simply by changing from an indoor antenna to an outdoor, mast-mounted antenna.* The span can be even wider (30-dB or more) if a mast-mounted preamp is used to minimize the effect of downlead attenuation.

Knowledge of the receive antenna system and deployment (*e.g.*, indoor versus outdoor) used by a given TV receiver is not generally available to an outside entity. whether that entity is a smart-radio device transmitting in locally unused TV spectrum or an analyst assessing potential for interference between two DTV broadcast stations. Even if a potential interferer to DTV reception had access to complete, accurate information regarding desired and undesired signal field strengths in a given DTV reception area, there would he no way to know where within a 30-dB signal level span that a given DTV receiver is operating without knowing the gain, height, or indoor-versus-outdoor placement of its antenna. Thus, for example, a given receiver could be operating with a 1-dB signal margin (at $D = D_{MIN} + 1$ dB, or about -83 dBm) or at the ATSC "moderate" signal level (D = -53 dBm), based only on changes in the antenna system.

Table 2-4. UHF Reception Examples

	Outdoor Reception w/Mast-Mounted Preamp[1]	Outdoor Reception (OET-69)	Indoor Reception (Low Gain Antenna)[2]
Antenna oain (dBd)	10	10	0.0
C			
Antenna height (m)	10	10	2.0
Relative field strength due to height difference (dB)[3]	0	0	-14.0
Building loss (dB)[4]	0	0	5.0
Relative signal level at input to TV (dB)	10	6	-19.6

Notes
[1] *Mast-mounted* preamp **is** assumed to have gain sufficient to overcome downlead **loss.**
[2] *Download* **loss** for indoor antenna is based on **2** meters of **RG-59** at **573** MHz (geometric mean frequency between channel **14** and channel **51).**
[3] Signal-strength dependence on height is based on the Egli propagation model, in which received signal power is proportional to the square of antenna height *(Egli, J.,* "Radiowave propagation above **40** Mc over irregular terrain': Proceedings of the **IRE, Vol. 45,** Oct. **7957, pp. 1383-1391)**
[4] Building loss attenuation shown is intended only as an example – not as an endorsement **of** a *particular* value

Despite the variation of D/U rejection ratios of TV receivers with absolute signal amplitudes, the *D/U ratio* formulation is convenient to use in applications like DTV-into-DTV interference assessment because estimation of D/U ratios may be easier and more accurate than estimation of absolute levels where long-distance propagation is involved — especially if the broadcast stations are co-sited. In such applications a change in antenna gain, height, or indoor-versus-outdoor placement are likely to affect the desired and undesired signal levels in the same way, so that the D/U ratio to which the TV is exposed remains constant with antenna changes (assuming that the undesired and desired signal sources both fall within the main response of the TV directional pattern). The lack of knowledge of the reception antenna means that interference assessment might have to consider a range of rejection ratios that are possible for the receiver given the range of signal levels that could reach the TV RF input from the range of likely antenna systems to which the potential victim TV receiver might be attached.

On the other hand, some may find *absolute* undesired *signal level thresholds* to be more useful for assessing shorter distance interference from low-power devices because the effects of TV antenna height

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* This data was based on a simple, flat-terrain propagation model. The results are intended only to illustrate that signal level at the input to a TV receiver can vary substantially with changes in antenna type and placement.

and placement on the undesired signal are likely to be different from their effects on the desired signal. In such cases, it may be useful to assess interference by determining the *absolute* level of an undesired signal that could cause picture degradation under the assumption that the TV could be operating at a low signal margin.

Because of these differences in approach, this report presents the interference rejection performance measurements in two ways: as D/U ratios and **as** threshold values for the undesired signal level U.[*]

TEST SUMMARY

Table 2-5 summarizes the tests performed for this report, including local-oscillator sensing and over 2000 measurements of DIU ratio.

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[*] This **is** more than just a convenience. For fixed desired signal levels, **one** can easily translate data between threshold U values and D/U ratios; however, for desired signals levels that are receiver dependent (*e.g.*, $D_{MIN}+3db$) the desired signal power necessary to convert between the two formats may be lost to the user for results that are presented as, for example, median across eight receivers or second-worst of eight receivers

Table 2-5. Summary of Tests

Test	Chap-ter	# of TV Receivers Tested	TV Tuned Chan (N)	Interference Channel	Interferer Type	Desired Signal Levels	# of D/U Measurements
Tuner Type Tests (e.g., Single/Double Conversion)							
Local-oscillator (LO) sensing	3	30 (11,5th-G)	51 & 53	N/A	N/A	N/A	
Interference rejection when not resolved by LO sensing	3	2 (4th G or earlier)	30	N+2 to N+16	WGN*	N/A	30
Interference Rejection—Single Interferer							
Channel 30 tests	5	8 (5th G)	30	N-16 to N-1, N+1 to N+16	8-VSB: N±1. WGN[1]: N±2 to N±16	D_{MIN}+3 dB, -68, -53, -28 dBm	1024
Channel-51 tests	6	7 (5th G)	51	N+1 to N+16	8-VSB	-68, -53, -28 dBm[2]	225
Channel-51 detailed tests of one TV	11	1 (5th G)	51	N+1 to N+7, N+14, N+15	8-VSB	D_{MIN}+1 dB, D_{MIN}+3 dB, -78 to -8 dBm in 5-dB steps	98
Interference Rejection for Paired Signals (3rd-Order Intermodulation in TV Receiver)							
Channel-30 tests	9	8 (5th G)	30	N-5/N-10 to N-1/N-2 and N+1/N+2 to N+5/N+10	8-VSB for N±1; WGN[1] for all others	-68, -53, -28 dBm[3]	176
Channel-51 tests	9	7 (5th G)	51	N+1/N+2 to N+8/N+16	8-VSB for N+K; WGN[1] for N+2K	-68, -53, -28 dBm[2]	162
Channel-51 detailed tests of one TV	11	1 (5th G)	51	N+1/N+2 to N+4/N+8	8-VSB for N+1; WGN[1] for all others	D_{MIN}+1 dB, D_{MIN}+3 dB, -78 to -8 dBm in 5-dB steps	57
Interference Rejection—Comparison Tests with Different Sources							
Repeat test for consistency	7	8 (5th G)	30	N-6, N-4, N-3, N-2, N+2	WGN[1]	-68 dBm	40
OFDM Interference	7	8 (5th G)	30	N-6, N-4, N-3, N-2, N+2	DVB-H (5-MHz width)	-68 dBm	40
8-VSB Interference	7	8 (5th G)	30	N-6, N-4, N-3, N-2, N+2	8-VSB	-68 dBm	40
1-MHz wide Interferer	7	1 (5th G)	30	N-15 to N-1, N+1 to N+15	Gaussian noise (1 MHz)	-68 dBm	88
Higher quality desired signal	7	8 (5th G)	30	N-6, N-4, N-3, N-2, N+2	WGN[1]	-68 dBm	40
Interference Rejection—To Evaluate Test Method							
Alternative test setup w/bandpass filter	14	1 (5th G)	14, 15, 21 to 37	Channel 29 (N-8 to N-1, N+1 to N+8, N+14, N+15)	8-VSB	-68 dBm	18
Broadband Notched Noise	14	8 (5th G)	30	Chan 2 -69 w/notch for chan 29-31	Gaussian noise + band-reject filter	-68, -53 dBm	16
Screen-Room	14	1 (5th G)	30	N+7	WGN[1]	-68 dBm	1
TOTAL							**2055**

Notes (see next page):

Notes from Table 2-5:

5" G" *refers to receivers having multipath performance equivalent to that of 5th-generation Zenith demodulators; all others tested as having earlier-generation demodulators.*

D_{MIN} *is the desired signal level corresponding to the threshold of visibility (TOV) of picture degradation in the absence of interference.*

[1] *WGN = white Gaussian noise bandlimited to 5.38-MHz 3-dB width.*

[2] *Tests of one of the seven receivers tested channel 51 were incomplete. For that receiver: all tests at D = -68 dBm were completed; at D = -53 dBm, the single-interferer tests were completed, but the paired-interferer tests were performed only for N+1/N+2; at D = -28 dBm, the only tests performed were N+1 and N+1/N+2.*

[3] *Channel-30 paired-signal tests at D = -28 dBm were limited to N+1/N+2 and N-1/N-2.*
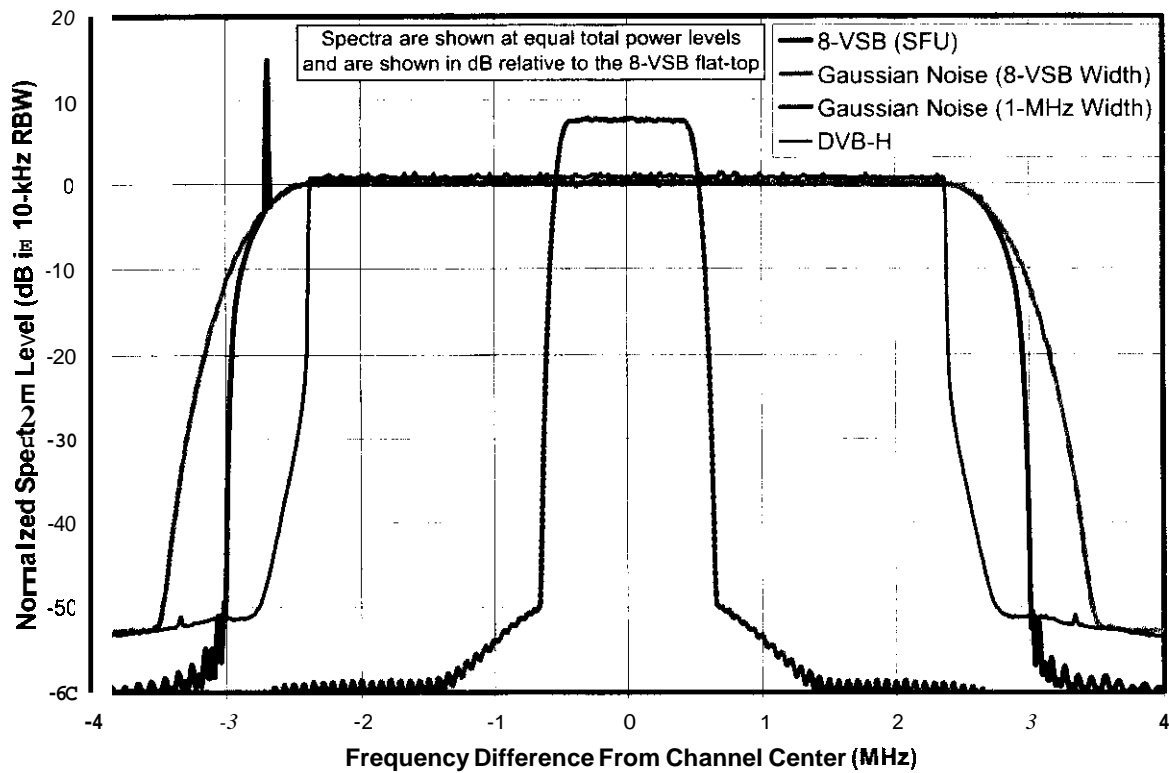
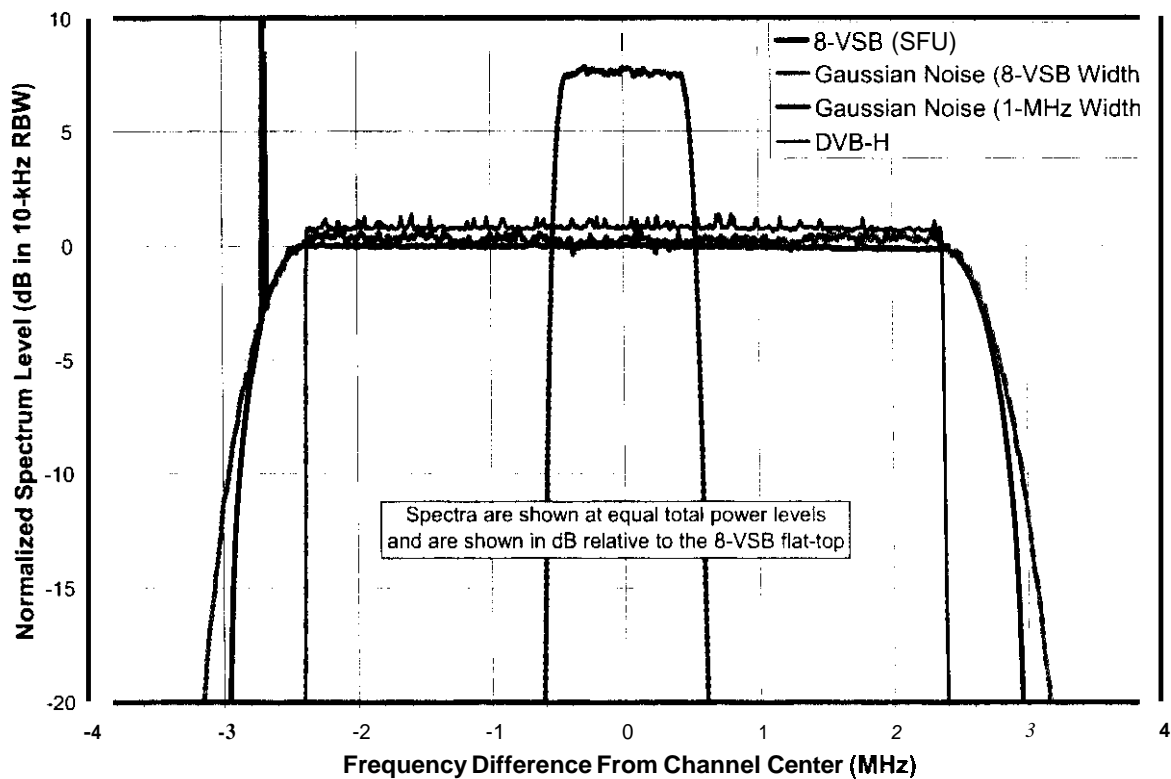*Figure 2-1. Spectra of the Four Undesired Signal Sources*

Figure 2-2. Spectra of the Four Undesired Signal Sources—Expanded Scale
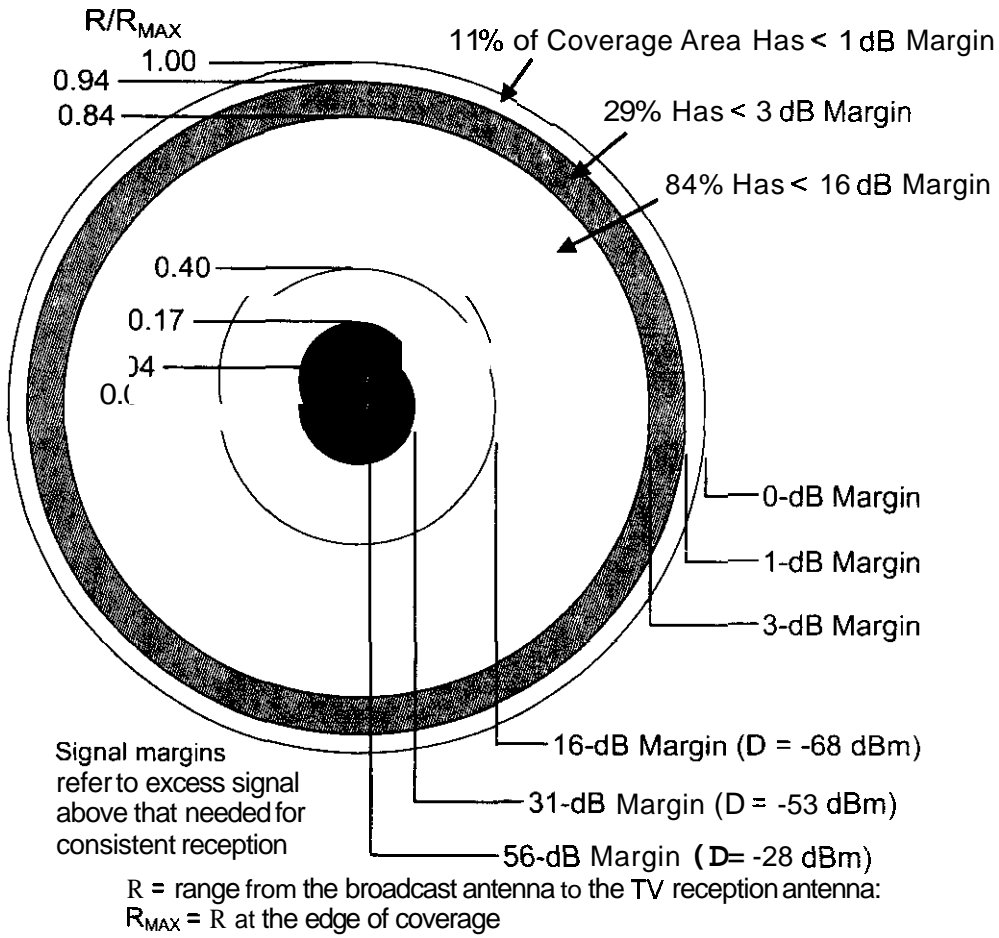
Figure 2-3. Relationship Between Signal Excess and Coverage Area

CHAPTER 3
TUNER TYPE TESTS

This chapter presents the results of tests of 30 DTV receivers to determine their tuner topologies

TUNER TOPOLOGIES

Two tuner topologies are known to have been used in ATSC DTV receivers: single-conversion tuners and double conversion tuners.

Both types of tuners are designed to shift a desired, 6-MHz wide TV signal from its original frequency (centered between 57 MHz for channel 2 and 803 MHz for channel 69) to a lower. fixed frequency range where it is feasible to implement a filter that passes the desired channel without significant distortion of its spectral shape while providing a high degree of rejection of adjacent-channel signals. Typically such a filter is implemented at a center frequency of 44 MHz and passes frequencies from 41 to 47 MHz. A single-conversion tuner performs the frequency shift in one operation. A double-conversion tuner performs it in two steps.

Single-Conversion Tuners

Figure 3-1 shows a simplified block diagram of single-conversion tuner. The input filter may he broad enough to pass an entire TV hand, such as the UHF hand containing channels 14 through 69. A "tracking filter" in the RF section adjusts with the TV channel selection and passes the desired TV channel and perhaps several channels on either side. A local oscillator (LO) at a frequency 44 MHz above the center of the desired TV channel (*e.g.*, 739 MHz when the receiver is tuned to channel 51) is then non-linearly mixed with the amplified and filtered RF signal. This mixing down-converts the desired TV channel from its original frequency (*e.g.*, 695 MHz +/- 3 MHz. for channel 51) to 44 MHz +/-3 MHz, which can pass through the fixed-frequency IF filter that serves to perform the primary channel selection function.'

In addition to the desired TV channel — centered 44 MHz *below* the LO frequency — incoming signals that are located 44 MHz +/- 3 MHz *above* the LO are also down-converted into the IF filter band. For UHF channels, which occupy contiguous 6-MHz spectrum assignments. this corresponds to parts of the energy in TV channel numbers N+14 and N+15, where N is the desired channel number. The presence of these image signals can interfere with reception of the desired signal. One of the purposes of the tracking filter in a single-conversion TV tuner is to attenuate signals at the image frequencies before they reach the mixer in order to mitigate the interference potential.

Certain other signal interactions in a single-conversion tuner can create interference sensitivities at other channel spacings. These will be discussed later in this report.

Double-Conversion Tuners

Figure *3-2* shows a simplified block diagram of a double-conversion tuner—as implemented in the Grand Alliance receiver.' This tuner configuration does not use a tracking filter. Rather, the entire TV spectrum

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* The down-conversion also reverses the direction of the frequency spectrum because the local oscillator frequency is above the frequency **of** the incoming signal.
† The diagram omits automatic gain control elements and lumps the first IF filter into a single filter located atter the first IF amplifier; the actual implementation included filters before and after rhe first IF amplifier. A more detailed block diagram is available in the following reference:
Advanced Television Systems Committee. "Recommended Practice: Guide to the Use of the ATSC Digital Television Standard, ATSC Doc. A/54A, 4 December 2003, Figure 9.2, p.86.

is up-converted in such a way as to center the desired TV signal at 920 MHz. After filtering, the resulting signal **is** then down-converted by the second mixer so that the desired signal **is** centered at 44 MHz.

Comparisons

The double-conversion design results in image frequencies that are further separated from desired signal as compared to a single-conversion design. This separation makes it easier to filter out those undesired signal components. A double-conversion receiver **is** therefore **less** likely to have detectable image responses.[*][†]

On the other hand, the lack of a tracking filter in double-conversion designs means that the first mixer must process all received TV signals rather than just the few channels surrounding the desired signal. Non-linear interactions between these various signals can create other interference issues.'[§] Additionally, achieving low noise figure and phase noise **is** more difficult in double-conversion than single-conversion receivers.[**][tt]

LO MEASUREMENT FOR TUNER TYPE IDENTIFICATION

In a single-conversion tuner, the LO frequency is located within the TV hands except when tuning the upper channels of a band. **A** small amount of the LO signal can leak out through the antenna port of the TV receiver. If the LO **is** detectable at the antenna port, **its** presence and frequency can be used to identify the tuner as single conversion and to confirm the IF frequency.

With double-conversion tuners. the LO is located above the UHF TV bands and **is** thus more easily filtered out and less likely to be detectable at the antenna port."[§§]

LO Frequency Test Methodology

The antenna port of each of the 30 DTV receivers discussed in Chapter 2 was observed using a spectrum analyzer in search of LO emissions. (For receivers having multiple antenna inputs that could handle **ATSC** signals, only the input labeled "antenna **A**" or "antenna 1" was tested.) During these tests, no signal was supplied to the antenna port; however, prior to these tests, a channel scan was perfoimed on each TV while simultaneously applying ATSC signals on UHF channels 51 and 53. This step was necessary because many DTVs prevent selection of a given TV channel unless a valid signal was observed on that channel in a previous channel scan.

To improve the detectability of very weak LO emissions, the spectrum analyzer was operated with 0 dB input attenuation, the internal preamp turned on, resolution bandwidth set to 10 kHz, and trace averaging enabled. The analyzer was set to sweep a **20** MHz span that included the frequencies of interest. Use of a

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[*] N. Scheinberg and others, "A GaAs Up Converter integrated Circuit for a Double Conversion Cable TV 'Set-Top' Tuner", *IEEE Journal of Solid-State Circuits,* Vol. 29, *No.* 6, June 1994. p.688

[†] Wayne Bretl and others, "VSB Modem Subsystem Design for Grand Alliance Digital Television Receivers", *IEEE Transactions on Consumer Electronics. Vol.* 41, No. **3,** August 1995. p.773.

[‡] Scheinberg and others, 1994, p.688

[§] Nick Cowley and Robert Hanrahan, "ATSC Compliance and Tuner Design Implications", *Electronic Engineering Times,* May 1, 2006. (http://www.eetasia.com/ART 8800416208 480700 f6d4765f200605.HTM)

[**] Yiyan Wu, "Performance Comparison of ATSC 8-VSB and DVB-T COFDM Transmission Systems for Digital Television Terrestrial Broadcasting".*IEEE Transactions on Consumer Electronics,* Vol. 45. No.3, August 1999, 922.

"Charles W. Rhodes, "Interference Between Television Signals due to Intermodulation in Receiver Front-Ends". *IEEE Transactions On Broadcasting,* Vol. 51, No. 1, March 2005, p.36.

[tt] John Henderson and others, "ATSC DTV Receiver Implementation", *Proceedings of the IEEE,* Vol. 94, No. 1, January *2006,* p.125.

"Wayne Bretl and others, 1995, p.773.

2001-point sweep enabled a 0.01-MHz bin-to-bin spacing. Each TV was initially tuned to channel 51 and the spectrum was observed for the presence of a line at 739 MHz—the LO frequency expected for a single-conversion tuner with a 44-MHz IF when tuned to channel 51. The TV was then changed to channel 53, the spectrum averaging was restarted, and the spectrum was observed to determine whether the line shifted upward by 12 MHz to the LO frequency expected for channel 53.

LO Test Results

For **28** of the tested 30 DTV receivers, LO signals were detected at frequencies consistent with a single-conversion receiver with an IF frequency of approximately 44 MHz. For 25 of those, each observed LO-associated line was within 0.02 MHz of the value expected (44 MHz above the center frequency of the tuned channel) for each tested channel. One of the receivers (designated O1 in the SHVERA Study) exhibited LO-associated lines that were 0.18 MHz above the expected frequencies. The LO-associated emissions from two other receivers (designated D2 and D3) exhibited a hunting behavior around the expected frequency—extending **as** far **as** 0.25 or 0.26 MHz from the expected frequency.

These results provide clear evidence that at least 28 of the 30 consumer DTV receivers that were tested have single-conversion tuners with an IF frequency at, or very near, 44 MHz.

For two of the receivers (designated G3 and P1), no LO signal was observed in the expected frequency range. Based only on these results, each of these two receivers could have had a different tuner topology, such **as** a double conversion tuner, or they could have had single-conversion tuners but either with a different IF frequency than was expected or with better control of LO leakage to the antenna port than the other receivers; consequently, a conclusion regarding topology of these two receivers required additional tests.

INTERFERENCE REJECTION TESTS FOR TUNER TYPE IDENTIFICATION

Interference rejection tests were performed for the receivers G3 and P1, the two receivers for which LO sensing was inconclusive. These two DTVs would he classified as fourth-generation or earlier[*] based on their multipath performance, which was tested **as** part of the SHVERA Study. Both were on the market in **2005,** though P1 was actually introduced to the market in 2004.

The measurements were performed using techniques to he described in the next chapter. **A** desired signal of -68 dBm was applied to the receivers on channel **30** along with a white noise signal bandlimited to a 3-dB width of 5.38 MHz on another channel. The undesired signal level was adjusted to the TOV of degradation of the television picture. The resulting D/U ratios are plotted in Figure 3.3.

Both receivers exhibit a peak in sensitivity to interference at N+7. This channel contains the LO frequency of a single-conversion tuner with 44-MHz IF. Such a peak can he observed in DIU plots presented in a later chapter of this report for seven of the other eight single-conversion receivers tested

In addition, receiver P1 exhibits elevated sensitivity to interference at N+14 and N+15. This corresponds to the mixer image for a single-conversion tuner with 44-MHz IF. Mixer image peaks are seen in D/U plots presented later in this report for seven of the eight single-conversion receivers tested.

Based on these observations, receivers *G3* and P1 are judged to have single-conversion tuners with 44-MHz IF. No further testing was performed on these two receivers.

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[*] The term "fifth generation" in this report refers to DTV receivers that exhibit multipath performance equivalent to that of Zenith fifth-generation demodulators. These two TVs exhibited multipath performance well below that level.

SUMMARY

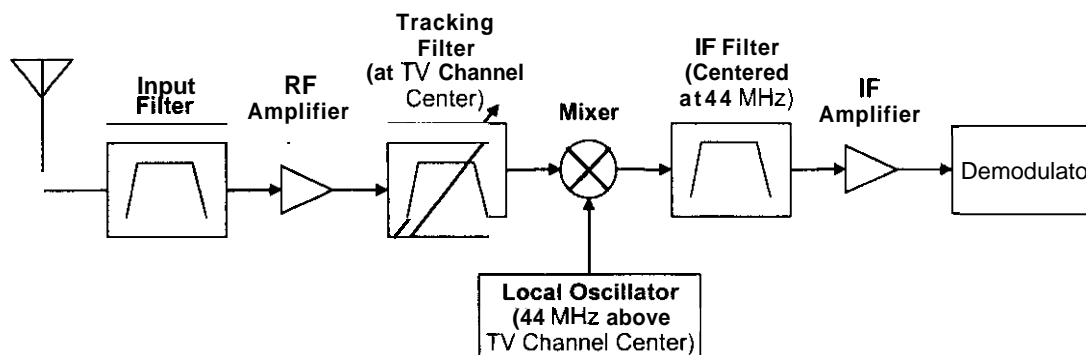**All** 30 tested receivers were judged to have single-conversion topologies with 44-MHz IF.

Figure 3-1. Single-Conversion DTV Timer Block Diagram Example
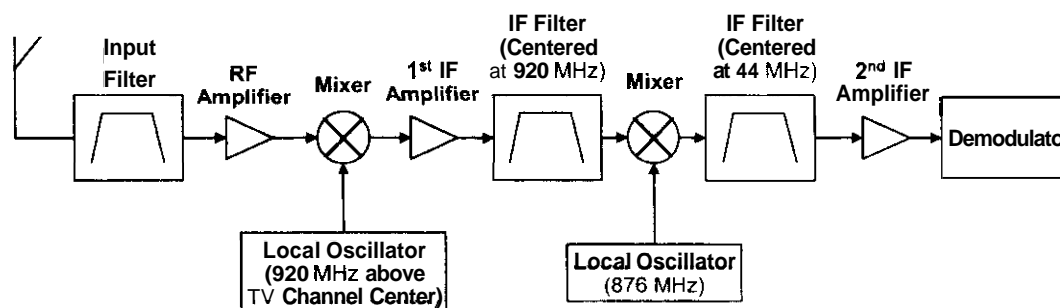

Figure 3-2. Double-Conversion DTV Tuner Block Diagram Example
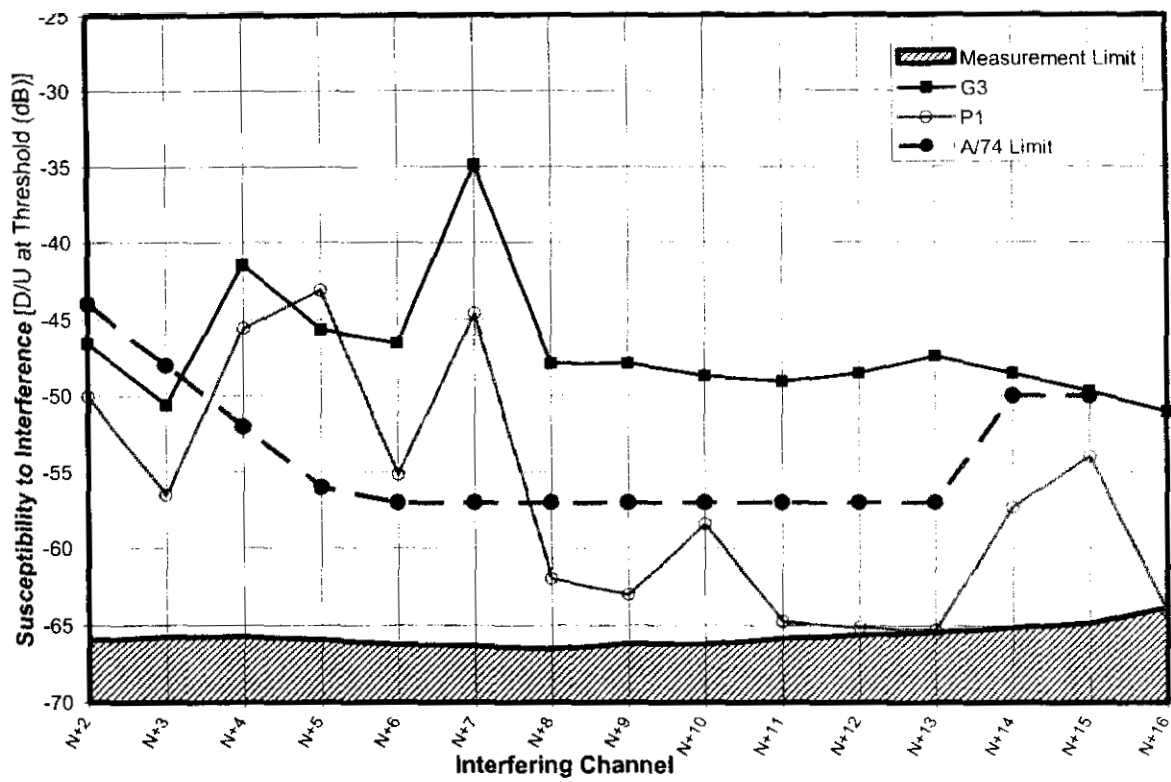
Figure 3-3. Rejection Performance of Receivers with Undetected LO's

CHAPTER 4
INTERFERENCE REJECTION REFERENCE LEVELS AND TEST METHODOLOGY

This chapter describes the test methodology employed for interference testing. the performance of the test setup, and some reference values for rejection performance from other documents.

Channel-to-channel signal level differences required for out-of-channel interference rejection testing present some challenges that require the use of specialized filters. The amount of filtering depends on the threshold desired-to-undesired (DIU) power ratios that are to be measured.

REFERENCE LEVELS FOR INTERFERENCE REJECTION PERFORMANCE

Interference rejection performance is defined in terms of the ratio of desired signal power (D) to undesired signal power (U) at the point at which visible degradation begins to occur in the television picture.

Grand Alliance Receiver Performance

The interference rejection capability achieved by the Grand Alliance prototype DTV receiver for a DTV interferer is shown in Table 4-1.

Table *4-1.* Grand Alliance Receiver Interference Rejection *Performance*

K	D/U Ratio (dB)	
	N – K	N + K
1	-41.98	-43.17
2	-60.52	-59.13
3	-60.61	-61.53
4 to 15	Not measurable	Not measurable

Interfering Channel	D/U Ratio (dB) for DTV-into-DTV Interference
N-1	-26
N+l	-26

For other channel offsets, OET-69 states the following

*"**The** evaluation of service **and interference** in **Appendix** B of the **Sixth** Report and Order considered taboo channel relationships for **interference** into DTV. However. the D/U ratios (approximately -60 dB) were such that they **rarely** if ever **had an** effect on **the** results, **and** the FCC rules adopted in the Sixth Report **and Order** do **not require attention** to UHF **taboo** interference to DTV stations."* [*]

Thus, the interference rejection threshold of -60 dB assumed for DTV receivers was considered adequate to protect against DTV-into-DTV interference for channel spacings beyond N+I and N-1 based on the allotment scenarios that were evaluated.

ATSC Recommended Performance

The ATSC Receiver Guidelines' recommend that DTV receivers achieve the interference rejection capabilities shown in Table 4-3. The performance thresholds are specified at three different desired signal levels, which the ATSC designates as "weak", "moderate", and "strong".

Table 4-3. ATSC A/74 Recommended Thresholds for Receiver. Interference Rejection

Interfering Channel Number	Threshold D/U for Specified Desired Signal Level (dB)		
	Weak (-68 dBm)	Moderate (-53 dBm)	Strong (-28 dBm)
N+/-1	-33	-33	*-20*
N+/-2	-44	-40	*-20*
N+/-3	-48	-40	*-20*
N+/-4	-52	-40	*-20*
N+/-5	-56	-42	*-20*
N+/-6 to N+/-13	-57	*-45*	*-20*
N+/-14 to N+/-15	-50	*-45*	*-20*

Notes
***Channel "N"** is **the channel** number of the **"desired"signal—** to which the DTV receiver is tuned.*
***Bold Italics** denote D/U thresholds that correspond to an undesired signal **level** of -8 dBm.*

It should be noted that the ATSC-designated "weak" and "strong" levels do *not* bound the range of expected signal levels. The document recommends that receivers be able to operate with DTV signals ranging from -83 dBm to -8 dBm in level.

The ATSC document explains the basis for the -33 dB rejection ratio for first-adjacent channel interference in Table 4-3. It points out that the OET-69 protection criteria for allotting DTV stations permits a D/U ratio as low as -26 and -28 dB for first-adjacent channel interference. The recommended -33 dB receiver threshold was obtained by subtracting 6 dB from the mean of these values. Since the criteria in OET-69 are derived from receiver susceptibility to transmitter splatter into the first adjacent channel (based on the DTV emission mask), a receiver threshold of -33 dB, measured without splatter, ensures that the factor determining adjacent channel interference will be transmitter splatter rather than receiver performance.

The ATSC document does not explain the basis of the other DIU values it recommends; however. those identified by red italics in the above table correspond to interference at the maximum expected DTV

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signal level of -8 dBm. We understand the other values to be a result of negotiations that considered the performance levels that would likely he achievable by consumer-grade TV receivers.

TEST SETUP REQUIREMENTS

<u>Measurement Requirements</u>

Goals for performance of the test setup were established based on the above reference levels. For first-adjacent channels (N+1 and N-1), our goal was to able to measure threshold D/U ratios **at** least **as** low as the -33 dB level recommended by the ATSC Receiver Guidelines. For all other channel spacings, or goal was to he able to measure down to a D/U ratio of **-60** dB.

We **also** wished to be able to supply desired and undesired signals at levels up to -8 dBm.

<u>The Challenge</u>

Consider the case of a D/U ratio of -60 dB—meaning that the desired TV signal power is 60 dB below the power of the interferer. The SHVERA Study demonstrated that the median DTV receiver requires that the desired signal he at least 15.3 dB above any co-channel noise in order for successful reception to occur.' For testing at a DIU ratio of -60 dB, this means that the co-channel noise created by the test setup must he at least 60 + 15.3 dB below the power of the interferer; otherwise, the test setup itself will prevent successful DTV reception. In fact, in order to make test setup noise relatively insignificant at a D/U ratio of -60 dB, we want an additional 10 dB margin— meaning that co-channel noise created by the test setup must be at least 85.3 dB below the power of the undesired signal when that signal is placed on any channel other than a first-adjacent one.

No available signal sources met this requirement. The source used to generate the "undesired' signal for the testing on channel 51 achieved only a 49-dB spread between signal power and power splattered into the second-adjacent channel (*i.e.*, power splattered into channel N when the undesired source was placed at channel N+2). The source used for most of the testing on channel 30 was somewhat better but still achieved only a 56 dB spread between signal power and splatter into the second-adjacent channel.

The -33 dB D/U specification placed on first-adjacent channel interference requires a less formidable sounding dynamic range. For that measurement, any noise created by the test setup must he at least 33 + 15.3 + 10 dB = 5X.3 dB below the power of the interferer. This specification was not met in the first adjacent channel of any source available during most of the testing.

To achieve the required test setup performance levels, a filter **is** needed to further reduce the out-of-band components of the undesired signal source.

<u>Solutions</u>

A typical solution to this filtering problem is to bandpass filter the undesired signal to reduce energy leakage into the desired channel. Because variable filters tend to have poorer shape factors than high-quality fixed filters, one approach would be to select a fixed interfering channel for the tests and to procure a fixed filter to shape the undesired signal on that channel. Testing at various channel spacings between the desired and undesired signals could be accomplished by switching the *desired* channel number over some required range.

While this approach would work well for tests with a single interferer, it creates a problem for testing against a pair of interferers. Intermodulation effects in the DTV receiver are expected to he most

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[*] Martin, <SHVERA Study>, 2005, chapter 3.

prominent for specific pairs **of** interfering signal channels, such as N+1 and N+2, N+2 and N+4, or **Nt3** and N+6. For tests of those effects, one interferer could operate on a fixed channel, but the other would have to be movable.

To deal with this problem, the desired channel was fixed and the undesired channels were allowed to change. The undesired signals were then subjected to a band-reject filter at the desired channel frequency. This fixed band-reject filter served to reduce leakage of the undesired signals into the desired TV channel.

In actuality, for a given desired channel, two custom filters were procured: one for adjacent-channel tests and the other for interferers located beyond the first-adjacent channel. Of the two filters, the filter for non-adjacent tests has greater rejection in the desired channel, but would cause unacceptable spectral distortion of an undesired signal on the adjacent channel (N+1). The filter for adjacent tests avoids excessive distortion to a first-adjacent undesired signal; it has less rejection in the desired channel than the other filter, but the rejection is sufficient for measurements at the more modest D/U ratios required for the first-adjacent channel.

In addition, the more conventional bandpass filter approach was implemented for one set of tests for comparison.

TEST SETUP

Figure 4-1 shows an overall block diagram of the test setup used for interference rejection tests

The top left portion of the diagram shows the desired DTV signal source and associated amplifiers, along with a step attenuator allowing signal level to he adjusted in 0.I-dB steps over an XI-dB range. **A** Sencore ATSC997 8-VSB generator playing a built-in high-definition video stream of a football game was used for most of the testing. A Rohde and Schwarz SFU generator, acquired relatively late in the test program, was used for tests at a low desired signal level (D_{MIN} **+ 3** dB) and for some comparative tests; a built-in high-definition video stream of a shark tank served **as** the video content for those tests. In the final two weeks before the due date of this report, some adjacent-channel testing was performed using a newly acquired Wavetech WS2100 RF Player, combined with an external upconverter and a file containing an 8-VSB signal mathematically derived from an MPEG2 transport stream,' to create a higher quality desired signal source than the Sencore ATSC997, while freeing the SFU to act **as** undesired signal on the adjacent channel.

Up to two generators were used at any given time to create the undesired (*i.e.*, interfering) signals. The generators included a Sencore RFP910 RF Player playing a supplied recording ("Hawaii Reference **A").** the Rohde and Schwarz SFU mentioned above, two Agilent **E4437B** vector signal generators used to generate band-limited white Gaussian noise, and an Agilent 4438C vector signal generator equipped with Signal Studio for DVB software to generate an OFDM DVB-H signal. The Sencore RF Player failed near the end of the planned tests at channel 51 and was unrepairable. The Robde and Schwarr SFU was procured later in the testing period.

The two undesired signals are combined and amplified by a 5-watt power amplifier which is operated at an output power of only 0.07 watts in order to limit third-order intermodulation distortion products. which would fall within the desired signal channel. **A** step-attenuator (Atten-C) is used to adjust the input level of the amplifier.

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* The file **was** provided by Mark Hryszko of the Digital Television group of Advanced Micro Devices

The amplified, undesired signal pair is then passed through one of four band-reject filters to reduce out-of-band splatter into the desired channel to which the TV is tuned. The filter is followed by a fixed attenuator and a step attenuator that allows the undesired signal level to be adjusted in 0.1-dB steps over an 81-dB range. **No** active devices (*e.g.*, amplifiers) are included in the test setup beyond the filter output in order to avoid creation of intermodulation products.

The desired signal is then combined with the filtered undesired signal pair. The combined signals are split into two paths—one feeding the DTV receiver under test through an impedance-matching pad and the other feeding a spectrum analyzer used for **all** power measurements. **A** total of about 9-dB of attenuation is provided in each splitter output path in order to reduce the impact of any reflections caused by impedance mismatches at the DTV receiver input. The attenuators following the splitter were selected to provide a signal level match between the TV port and the measurement port to within 0.1 dB across **all** TV channels.

Double-shielded cables were used throughout the test setup because of the wide range of signal levels present simultaneously. **A** 50-ohm impedance was maintained throughout the setup, except at two 8-VSB sources and the consumer TV inputs, which were each specified to be nominally 75 ohms. The 75-ohm devices were matched to the rest of the test setup through impedance-matching pads or—in the case of one of the 8-VSB sources—an impedance-matching transformer. In addition to the impedance-matching pads, **50-ohm** attenuator pads were used at various places throughout the test setups to reduce the effects of any impedance mismatches at places where such mismatches were considered likely or would be expected to have a significant impact, as well **as** to reduce third-order intermodulation in amplifiers **A1** and **A2.**

The test setup is capable of delivering undesired signals to the TV receiver at a maximum level ranging from -7 to -1 dBm per interferer.

TEST SETUP PERFORMANCE

As was described in the *Test Setup Requirements* section, the test setup was required to suppress splatter from the undesired signals into the desired channel by as much as 85.3 dB. No available spectrum analyzer had sufficient dynamic range to measure this degree of suppression. Instead, the spectrum of the output of the test setup was first measured with the filter bypassed. These measurements were performed with no desired signal present and for several different channel selections for the undesired signal with undesired signal set to a high level. Separately, the frequency response of the test setup was then measured both with the filter in place and with the filter bypassed; the difference between these measurements represents the in-situ filter frequency response. The filter frequency response **was** then applied to the spectrum measurements made with the filter bypassed—resulting in a computed value for the net output spectrum.

Figure **4-2** shows the output spectrum of the test setup with channel 30 as the desired channel and a bandlimited white Gaussian undesired signal at channel N+2. Integration of the blue—undesired-signal-only curve shows that the power splattered by test setup into channel N is 99.3 dB below the total undesired signal power. About **56** dB of this suppression is due to the performance of the undesired signal generator—degraded slightly by the amplifier that follows it. The remaining 43 dB of suppression comes from the band-reject filter.

In the figure, the spectrum of a desired DTV signal is plotted at a total power level 60 dB below the power of the undesired signal, *i.e.*, at a D/U ratio of -60 dB. Since a typical DTV requires that D be 15.3 dB above any co-channel noise, the test setup noise is **24** dB below the point at which DTV

operation would fail. This significantly exceeds the IO-dB margin that was considered essential for meaningful DIU measurements.

Figure 4-3 shows another example of the output spectrum of the test setup—again with channel 30 as the desired channel, hut this time with a pair of interfering signals spaced to create intermodulation distortion in channel N. In this case the unintended power leaked into the desired channel is **98.2** dB below the undesired signal power.

Figure 4-4 shows an adjacent-channel example. A pair of interferers is placed at N+1/N+2. The interferer at N+1 (U_1) is an 8-VSB source; some rounding of the left side of the 8-VSB signal by the band-reject filter can be seen. The interferer at N+2 (U_2) is a white-Gaussian-noise source bandlimited to match the 3-dB width of an 8-VSB signal. Two different interferer types had to be used for this test: though two bandlimited noise generators were available, their spectrum rolloff is not steep enough for use as an adjacent channel (N+1) source because too much power would be spilled into the desired channel; and, only one 8-VSB source (besides the one used as a desired signal) was available.

In the case of N+1/N+2 interference, there is no need to measure DIU ratios as low as -60 dB. In this case, the desired signal is shown at a DAJ ratio of -33 dB—the ATSC-recommended rejection performance for first-adjacent-channel interference. Based on integration of the signal spectra, the total noise power leaked into the desired channel is 70.2 dB below the undesired signal power. This provides a 21.9 dB margin to the point of reception failure caused by the test setup. (Actual margin is likely higher than this because, as can be seen from the plot, much of the undesired power that leaks into the desired channel N is at the band edges where filtering within the DTV receiver will reduce its effect.) With 10 dB being considered the minimum acceptable margin, receiver measurements could be made with this signal configuration down to a DIU ratio of about -45 dB per undesired signal.

Table 4-4 summarizes the minimum DIU ratios that can be measured by the various test setup configurations used in this report based on the undesired signal leakage into the desired channel. Two limitations are listed for adjacent-channel test configurations: a limit based on total power leaked into the desired channel and a limit that includes the effect of a DTV receiver's raised-cosine filter response on spectrum leakage at the edges of the desired channel. The former limit ("worst case limit") is displayed on plots as the "Measurement Limit" for measurements on channel 30. The latter limit **is** used as a measurement limit for measurements at channel 51 to avoid unnecessarily excluding measurement results from further analysis. (This decision was made because the channel-SI test setup had poorer performance than that for channel 30, in that it spilled more energy from the undesired signal into the edge of the desired channel.)

In addition, minimum DIU ratio is limited by the maximum undesired signal level that the test setup can produce. The maximum undesired signal level ranges from about **-7** dBm to -1 dBm depending on the test setup configuration and channel spacing being tested. Typically, at a desired signal level of -68 dBm the DIU measurement range is limited by leakage of undesired signal into the desired channel for measurements at N+1 or N-1 and by maximum undesired signal that the test setup can generate for all other channel spacings.

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[*] The indirect measurement method used in generating the spectrum—measuring it without the filter, then adding in an in-situ measurement of filter response —would not identify any energy coupled by radiation into the test setup at a point after the filter or any spectral components created by intermodulation distortion occurring after the filter; however, the use of double-shielded cables throughout the test setup and the avoidance of using any active devices after the filter are expected to preclude significant degradation in test setup performance due to these factors.

TEST SETUP CONFIGURATIONS

Table 4-5 summarizes the equipment configurations used for the various tests of interference rejection performance.

Table 4-4. Measurement Limitations of the Test Setup

Desired Channel N	Filter	Undesired Source 1	Undesired Source 2	Applicable Interference Channels	Cases examined	Worst-Case Limit on D/U (dB)	DIU Limit If the DTV's Raised Cosine Filter Is Assumed in TV (dB)
30	30N	8-VSB (Rohde SFU)	None	N+1, N-l	Both	-48.3	-59.4
30	30W	WGN	None	N+2 to N+16 and N-2 to N-16	N-16, N-8, N-2, N+2, N+8, N+16	-74.0	
30	30N	8-VSB (Rohde SFU)	WGN	Pairs N+1/N+2 and N-1/N-2	Both	-44.9	-52.5
30	30W	WGN	WGN	Pairs: N+2/N+4 to N+8/N+16; N-2/N-4 to N-8/N-16	Pairs: N-8/N-16, N-4/N-8, N-2/N-4, N+2/N+4, N+4/N+8, N+8/N+16	-71.7	
51	P52-53	8-VSB (Sencore RFP)	None	N+l	N+l	-37.6	-43.9
51	P52-53	8-VSB (Sencore RFP)	WGN	N+1/N+2	N+1/N+2	-36.7	-42.6
51	P53-56	8-VSB (Sencore RFP)	WGN	N+2 to N+16 and pairs: N+2/N+4 to N+8/N+16	All pairs and N+9 to N+16	-71.0	

*Note: WGN refers to bandlimited while Gaussian noise from an Agilent E4437 vector signal generator*

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N	Interferer(s)	Test Setup	Desired Signal Source	Undesired Source 1	Undesired Source 2	Step Atten-C (dB)
Interference Rejection—Single Interferer						
30	Single adjacent	Primary	8-VSB Src A @ 38dBmV	8-VSB Src C @ +2 dBm		5
30	Single adjacent w/D at D_{MIN}+3 dB	Primary	8-VSB Src D	8-VSB Src C @ +2 dBm		5
30	Single non-adjacent	Primary	8-VSB Src A @ 38dBmV	WGN Src A @ -7 dBm		2
30	Single non-adjacent w/D at D_{MIN}+3 dB	Primary	8-VSB Src C @+2dBm	WGN Src A @ -7 dBm		2
51	Single	Primary	8-VSB Src A @ 38dBmV	8-VSB Src B @ -30 dBm		2
Interference Rejection for Paired Signals						
30	Paired adjacent (*e.g.*, N+1/N+2)	Primary	8-VSB Src A @ 38dBmV	8-VSB Src C @ +2 dBm	WGN Src A @ variable level	5
30	Paired non-adjacent	Primary	8-VSB Src C @+2dBm	WGN Src B @ -7 dBm	WGN Src A @ variable level	8
51	Paired	Primary	8-VSB Src A @ 38dBmV	8-VSB Src B @ -30 dBm	WGN Src A @ variable level	2
Interference Rejection—Comparison Tests With Different Sources						
30	Single non-adjacent DTV interferer	Primary	8-VSB Src A @ 38dBmV	8-VSB Src C @ +2 dBm		2
30	Single non-adjacent OFDM interferer	Primary	8-VSB Src A @ 38dBmV	OFDM Src A @ -6.9 dBm		2
Interference Rejection—To Evaluate Test Method						
Variable (U at 29)	Single adjacent & nonadjacent using Simplified Test Setup w/BPF on U	Alt	8-VSB Src A @ variable output level	8-VSB Src C @ variable output level		NA

est Setups
- Primary: Figure 4-1
- Alt.:   Figure 14-2

Signal sources
- 8-VSB Source A: Sencore *ATSC997* ATSC Source
- 8-VSB Source B: Sencore *RFP910* RF Player *("Hawaii_ReferenceA"* file)
- 8-VSB Source C: Rohde & Schwarz SFU 8-VSB Generator
- 8-VSB Source *D*:   Wavefech WS-2100 RF Player ("Muddy *Waters" file)* + Drake *DUC860 Upconverter*
- A WGN Source A: Agilent *E4437B* Vector Signal Generator in A WGN mode
- AWGN Source B: Agilent *E4437B* Vector Signal Generator in A WGN mode
- OFDM Source A: Agilent *E4438C* Vector Signal Generator + Agilent Signal Studio for DVB software
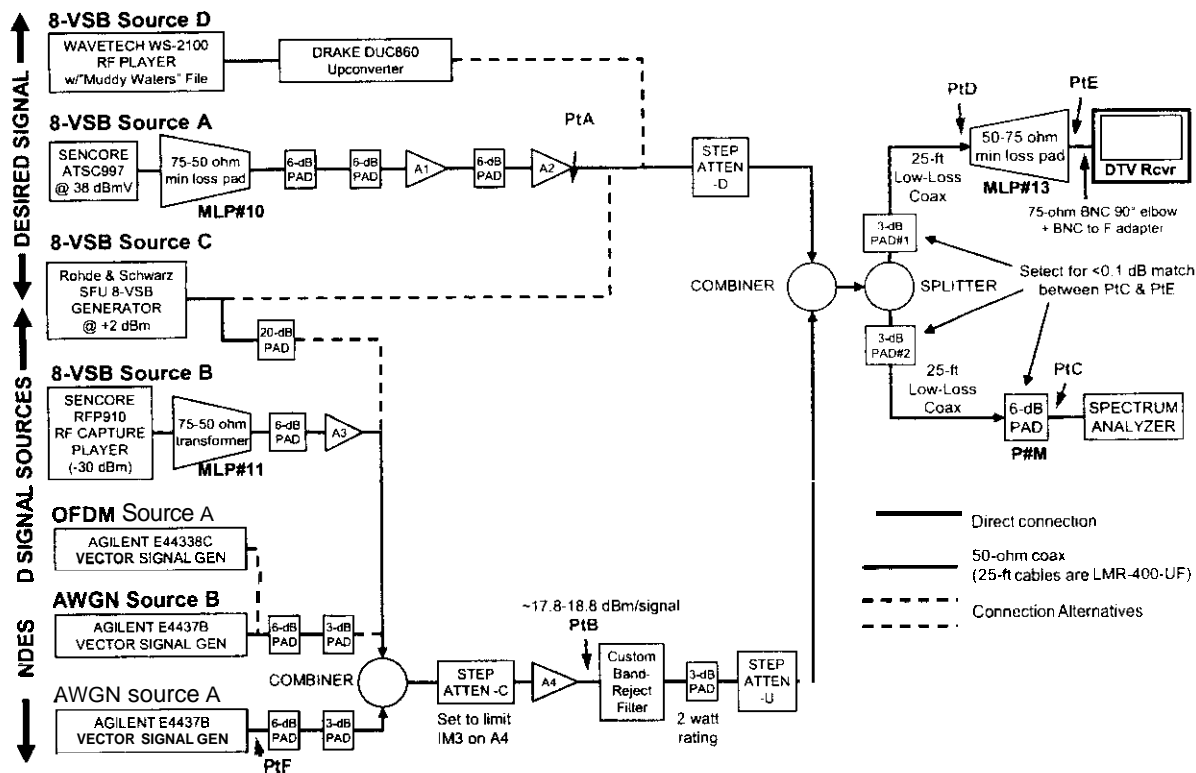
- Amplifiers
  - V A1 = Minicircuits ZFL-1000H (28 dB minimum gain; 20 dBm 1-dB compression)
  - V A2 = Minicircuits ZFL-1000VH (20 dB minimum gain; 25 dBm 1-dB compression)
  - 0 A3 = HP8447B (22 dB gain; 400-1300 MHz)
  - 0 A4 = Amplifier Research 5W1000 (37 dB gain; 500 kHz – 1000 MHz; 5 watts output)
- Attenuators
  - 0 Attenuators preceding A1 and A2 are selected to reduce IM3 to acceptable levels
  - V Step Attenuator-C set to reduce IM3 of A4 to acceptable levels
  - V Step Attenuators D & U: Alan Industries models 50V70 N, 50V10 N, and 50V1 N cascaded to provide 0 - 81 dB in 0.1-dB steps (0.5W max power)
- Combiners & Splitter: Minicircuits ZAPD-900-5W (100-900 MHz)
- Custom Band-Reject Filters
  - V "30N" = Tin Lee CE7-569(4.8)N50
  - V "30W = Microwave Filter Company model 16195
  - 0 "P52-53" = Tin Lee CE7-692/697.4(20) N50
  - V "P53-56" = Tin Lee CE7-692/698 N50
- Impedance Matching
  - V Minimum Loss Pads = Trilithic ZM-57
  - V 75-50 ohm transformer = Trilithic ZMT-57
- 25-ft coax = Times Microwave LMR-400-UF
- Equipment settings
  - 0 Agilent E44379 settings for bandlimited white Gaussian noise
    - – AWGN mode w/length 1048576
      - ⇒ Bandwidth setting = 4.686 MHz for 5.38-MHz 3-dB width
      - ⇒ Bandwidth setting = 875 kHz for 1-MHz 3-dB width
    - – Output setting = -7 dBm. (Higher could damage Step-Atten-U & raise IM3 of E4437B output)
  - 0 Agilent E4438C vector signal generator using Agilent Signal Studio for DVB software
    - – Signal Type: DVB-H
    - – Waveform parameters: Size=2k; Modulation=64 QAM; Chan. width=5 MHz; Guard interval=1/8
    - – Output setting = -6.9 dBm

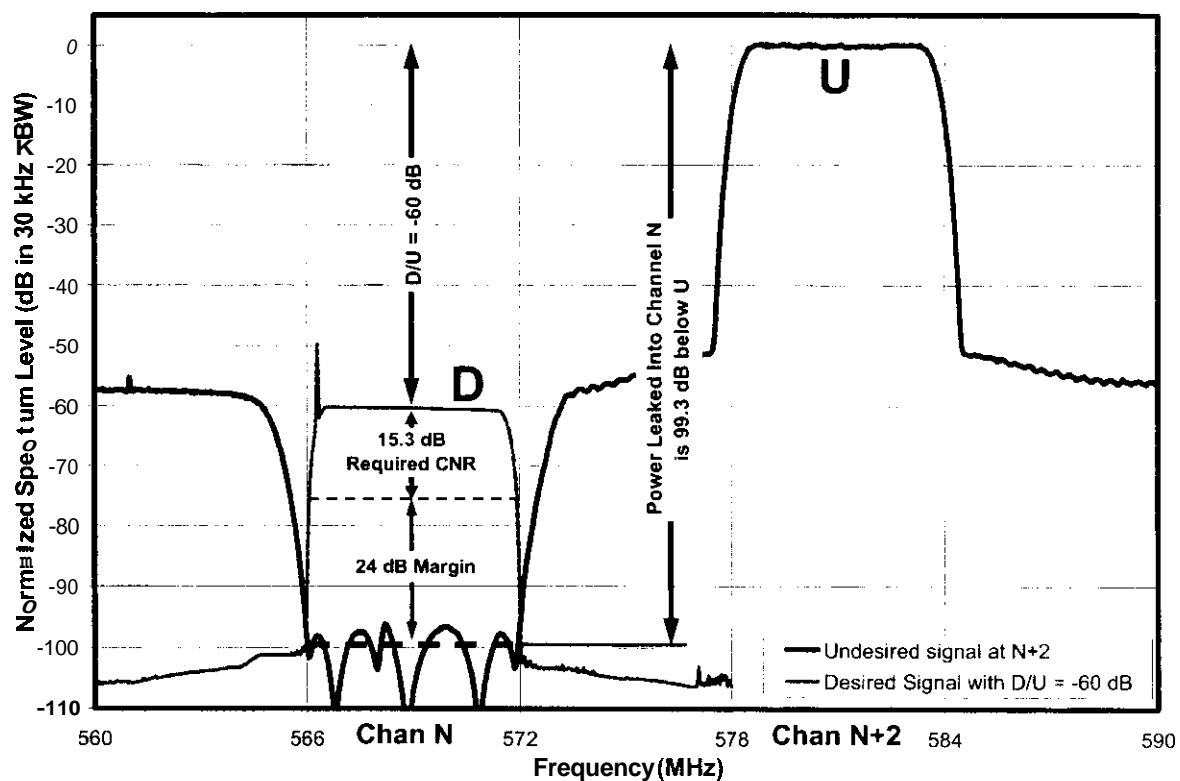*Figure 4-1. Block Diagram of Interference Rejection Test Setup*

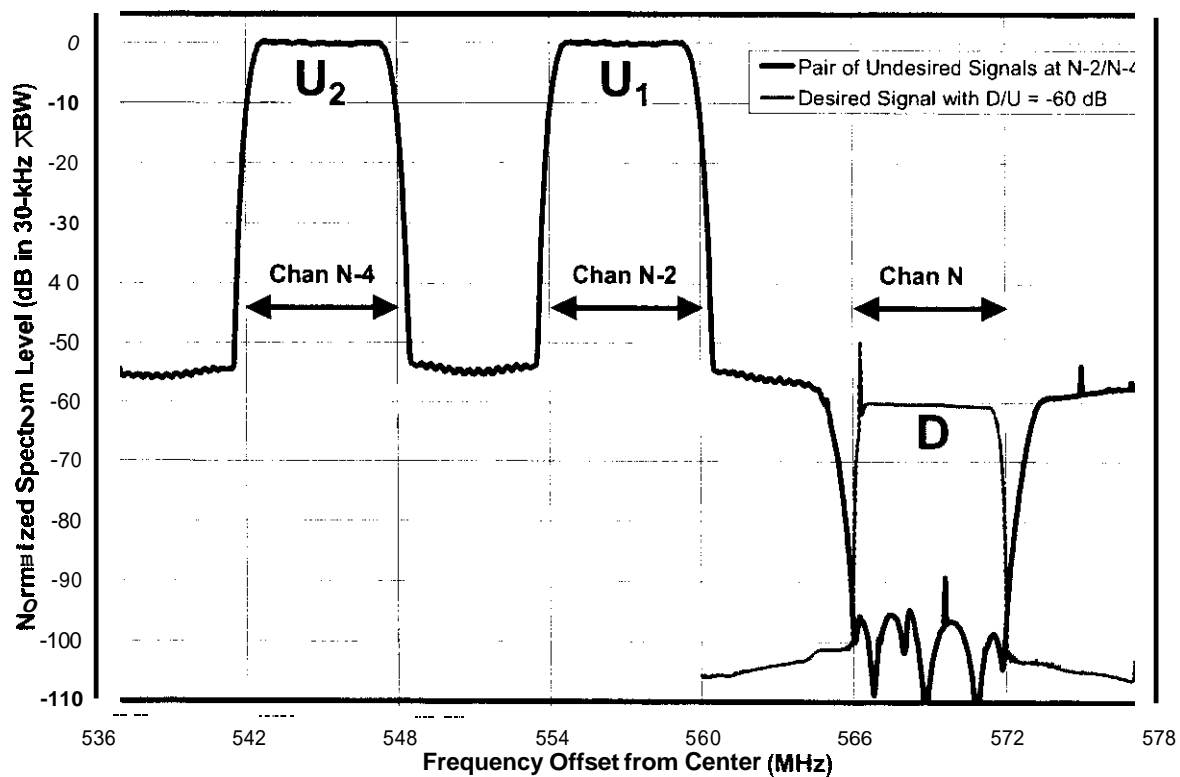*Figure 4-2.* **Leakage** of U at N+2 into **Channel N** (30)

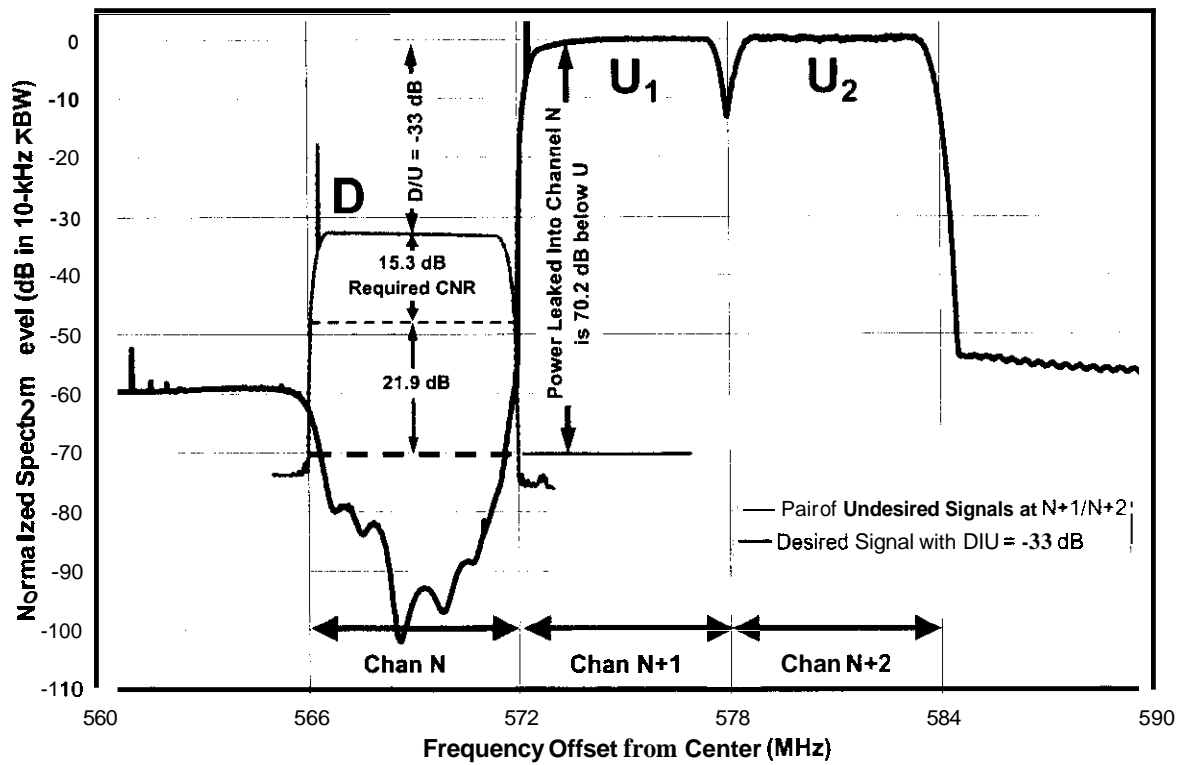*Figure 4-3.* **Leakage** of U pair at N-2/N-4 into Channel N (30)

Figure 4-4. Leakage of U pair at N+1/N+2 into Channel N (30)

CHAPTER 5
REJECTION RESULTS ON CHANNEL 30 FOR SINGLE INTERFERERS WITH FULL CHANNEL WIDTH

This chapter presents the results of interference rejection tests of eight "fifth-generation" DTV receivers tuned to channel 30. The interferer for these tests was:
- For channels N+I and N-1, an **8-VSB** signal;
- For channels N+2 through N+16 and N-2 through N-16, a white Gaussian noise signal bandlimited to match the 3-dB width of an 8-VSB signal.

Spectra of the sources were shown in Figures 2-1 and 2-2.

A limited set of interference rejection tests was also performed on two earlier-generation receivers, designated G3 and P1, for purposes of identifying tuner type as described in Chapter 3. This data was plotted in Figure 3-3, but it is repeated near the end of this chapter with an overlay showing the range of values measured for the fifth-generation receivers for comparison.

The primary focus of these tests was to investigate the interference susceptibility of DTV receivers operating in the UHF band to interference from other occupants of the UHF TV spectrum. including other TV broadcasts as well as non-TV use of the "white spaces". As such, the desired channel (30) was selected as a locally unused channel near the center of the UHF core spectrum.

Test results are presented in this chapter either **as** D/U ratios, in which case better performance corresponds to lower points on the graph, or **as** threshold values of the undesired signal level U, in which case better performance corresponds to points nearer the top of the graph

TESTS AT ATSC-SPECIFIED DESIRED SIGNAL LEVELS

"Weak" Desired Signal (D = -68 dBm)

Figure 5-1 shows measured values of D/U ratios at TOV for the eight DTV receivers for undesired signal channels ranging from N-16 to N+16. (The case of co-channel interference. *i.e.*, interference on channel N, is omitted.) The desired signal power was set to -68 dBm, a signal level that the ATSC chose to designate **as** "weak", although DTVs are assumed to operate down to a signal level of -84 dBm.[*]

The shaded area at the bottom of the plot represents the measurement limitations imposed by the test setup—as described in Chapter 4. Measurements falling in—or at the border of—this region are not valid; the actual performance of a receiver at these points is better (*i.e.*, lower on the graph) than the plotted point indicates. For N-1 and N+I with D = -68 dBm, the limit is based on leakage from the undesired source into the desired channel. For other offsets and higher desired signal levels, the measurements are limited by the maximum undesired signal power the test setup could inject into the DTV receiver.

The ATSC-recommended DTV-into-DTV interference rejection thresholds are shown on the plot as a reference. Those limits are defined for channels ranging from N-15 and N+15. Compliance with those

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[*] DTV allotment planning factors assume that a DTV receiver can operate at an input level of **-84** dBm on UHF channels. The ATSC Receiver Guidelines document recommends that receivers be able **to** operate with signal levels at least as low **as** -83 dBm. Measurements on 28 DTV consumer receivers in the SHVERA Study showed a median capability of -83.9 dBm at channel 30.

voluntary limits would be indicated by all points on a measurement curve falling on or below the ATSC line. It should be recognized, however, that the ATSC recommendations apply when the undesired signal is an 8-VSB DTV signal, which was the case only for the N-1 and N+1 points on each curve. It can be seen that all eight receivers comply with the ATSC recommendation at N-1 and N+1

At the other channel offsets, N-2 through N-15 and N+2 through N+15, no receiver appears to fully comply with the recommended performance limit. The best-performing receiver, designated G4, complied everywhere except at N+5 and N+6, where its performance failed to meet the limits by about 2 dB and 1 dB, respectively. On average, the receivers failed to meet the recommended performance on at about seven of the **30** channel offsets, with one receiver (D3) failing at twelve points. The worst failure for each receiver ranged from about 2 dB to 25 dB.

The above results cannot be viewed as definite failures to meet the performance guidelines because the tests (other than at N-1 and N+1) were performed using a bandlimited white noise source as the interferer. rather than an 8-VSB signal. (An 8-VSB source was not available for most of the test period.) Limited tests presented in Chapter 7 show an average performance improvement of 1.1 dB when the interference comes from an 8-VSB signal rather than from the white Gaussian noise source of the same 3-dB bandwidth. However, even taking this difference into account, it is unlikely that any of the receivers would fully comply with the ATSC guidelines at every channel offset. though one or two would probably come close.

Figure 5-2 summarizes the measurements that were shown in Figure 5-1. The blue curve shows the median performance of the eight receivers. Error bars show the best and worst performance among the receivers at each channel offset. A dashed curve shows the performance of the second worst performing receiver at each channel offset. On a median basis, the offsets that break the recommended limits by the largest amounts are N-4, N-6, and N+7.

"Moderate" Desired Signal (D = -53 dBm)

Figure 5-3 shows measured values of DIU ratios at TOV for the same eight DTV receivers with the desired signal power set to -53 dBm, a signal level that the ATSC designates as "moderate". Again, all eight receivers comply with the ATSC recommended performance on the first-adjacent channels (N+1 or N-1). At the other channel offsets, only one receiver (G4) appears to fully comply with the recommended performance limit. A second receiver (I1) appears to fail only at N-2 by 1 dB and at N-4 by a negligible amount. Other receivers fail at from one to 16 points with worst-case failures ranging from three to 18 dB. The worst performing receiver was D3. Again, these results cannot be viewed as definite failures to meet the guidelines because the tests were performed using a bandlimited white noise source as the interferer, rather than an 8-VSB signal. Based on the differences in interference effect of the 8-VSB and Gaussian signals, it is likely that a second receiver would have complied with the guidelines at this desired signal level if an 8-VSB signal had been used as the interferer.

Figure 5-4 shows the best, median, second worst, and worst performance at each channel offset. On a median basis the only failure to satisfy the ATSC recommended performance is at N+7.

"Strong" Desired Signal (D = -28 dBm)

Figure 5-5 shows that, with the desired signal set to the level that the ATSC designates as "strong", every receiver complied with the ATSC Recommended Guidelines at every point, with the exception of one receiver (G4) that appeared to fail by only 0.2 dB at N+1. In most cases the test setup was not capable of generating strong enough undesired signals to cause visible degradation of the TV picture; consequently, most data points are plotted on the measurement limit line. Figure 5-6 shows the best, median, second worst, and worst performance at each channel offset.